In the first place it seems to be purely a matter of chance what luck the germ-cells have in their mating, what particular ovum is fertilised by what particular spermatozoon, and, owing to the enormous numbers in which ova and spermatozoa are produced, the possibilities may be almost infinite. In the second place there are many alternative possibilities with regard to the particular factors which any given germ-cell, male or female, may contain. This depends upon which particular chromosomes happen to remain in the germ-cell after the double number has been halved again. In animals this halving takes place at the time when the germ-cells are ripening, shortly before they are ready to unite in the fertilised egg. The maternal and paternal chromosomes in each, differing as regards the factors they contain, pair off during the process of mitosis. The members of each pair then separate, and one of them alone remains in each mature germ-cell. Hence the germ-cells, even of the same individual, come to differ amongst themselves to a practically unlimited extent as regards their factorial constitution. The life of the individual is like a game of cards, in which a very great deal depends upon the shuffling of the pack, and the player has to do the best he can with the hand dealt out to him. He may make a hopeless failure of it, or a great success; but still the stream of life flows on, ever gathering and combining new experiences, ever forming itself into fleeting individualities and leaving them to perish on its banks as it passes on to fresh attempts at self-expression.

The interest of the Mendelian breeding experiments is so absorbing that it is little wonder if more fundamental aspects of the problem of heredity, to which we have alluded in the earlier part of our lecture, have been largely lost sight of in recent years, while the factorial hypothesis has been hailed by some extremists as the all-sufficient explanation of everything. The characters of the organism may indeed be modified by factors in the germ-plasm, just as the character of a loaf may be modified by putting caraway seeds into the dough; but the caraway seeds do not explain the loaf, and the Mendelian factors cannot explain the organism as a whole. There is doubtless a good deal of truth in the old saying that life is made up of trifles; but it is not the whole truth, and the body of a living organism cannot be regarded as merely the sum-total of its unit characters.

Whatever may be their significance from the point of view of the general theory of evolution and heredity, however, there can be but one opinion as to the immense practical importance of the Mendelian investigations. They have already led to the production of many valuable forms of life, more especially plants, that are to all intents and purposes new creations, although their value and novelty may depend merely upon the bringing together of desirable characters in new combinations and the elimination of undesirable features.

Nor are the possibilities of improvement by selective mating confined to our domesticated plants and animals. Hopes are entertained by many enthusiasts, banded together in the interests of what they have thought fit to term the science of Eugenics, of effecting vast improvements in the human race itself by the application of Mendelian principles. It does not seem likely, however, or even desirable, that men and women should ever consent to be guided in their choice of mates by purely utilitarian considerations.

There are many objections to any far-reaching schemes of this kind, but it does seem possible, when once the facts of heredity are generally known, that the exercise of an enlightened public opinion and individual choice may result in the elimination from the stream of human life of many heritable characteristics which it is very undesirable to perpetuate. In extreme cases, such as feeble-mindedness and certain forms of insanity, it may even be necessary for the community to protect itself by legislation against the criminal propagation of the unfit.

What is wanted, first and foremost, however, is education, and I trust that you will agree with me that it is education in biology—the science of life—to which we may most hopefully look for the physical and mental improvement of the human race. Men and women must learn to realise their responsibilities towards future generations from the biological point of view, and it is in this direction that the citizens of a great city like Edinburgh can best help, by generously supporting the cause of education and research as represented by your ancient and world-famed University.

Speech through the Æther.[1]

By SIR OLIVER LODGE, F.R.S.

AN intelligent deep-sea fish would disbelieve in water. It would be too uniform and omnipresent to make any impression on its senses. Near the surface it might encounter waves and currents, but to creatures thoroughly embedded in its depths water would make no display. Such is our own condition with regard to the æther of space. It eludes direct perception; its existence cannot be directly demonstrated; it has to be inferred.

The fish would probably also disbelieve in gravity, since it would not experience it, and some of the hyperintelligent among us, for quite another reason, seem to be following its example; but that is another story. Suffice it to say that direct sensation is but a poor clue to reality unless supplemented by a great deal of reasoning and indirect inferences. Our senses tell us only about matter, and to believe in anything else makes some call upon the imagination. By aid of cultivated imagination, however, the permanently deaf may appreciate something of the meaning of music, and the permanently blind may apprehend dimly the beauty of a landscape. So it appears from the experience of Helen Keller.

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[1] Abstract of a citizens' lecture of the British Association delivered at Edinburgh on September 6.

Let us grant, then, that the æther impinges on us only through our imagination; that does not mean that it is unreal. To me it is the most real thing in the material universe. It is not matter, but it seems to be the stuff of which matter is made. It holds the atoms together, and it welds the cosmos into a coherent whole. It penetrates the pores of matter even into the innermost recesses of atomic structure, and it extends to the furthest confines of visible space. By its aid we see and analyse the nebulæ at distances too vast for anything but mind. Through it, too, we do more prosaic things—we telegraph and we run electric motors—even tramcars—guiding the energy by a wire itself inert. Briefly summarised, the æther is responsible for cohesion, for chemical affinity, for electric and magnetic forces, for light, aye, and, as we learn from Einstein, for gravitation too. Is there anything the æther does not do? Yes, it does not convey sound. Sound is a vibration in matter, not in æther, while light is a tremor in æther, not in matter. We see through the æther; we do not talk through it.

But my subject is "Speech through the Æther," speech by means of what we call empty space. How can that be? How can we utilise the æther for conveyance of sound?

Only by transmutation. The æther has long been used to convey heat, yet heat is a property of matter. Heat from the sun reaches the earth, but it does not travel as heat. At the sun the quiver of the particles is transmitted to the æther, it spreads out as radiation, and where that falls it can excite a similar quiver. The heat disappears in one place, to reappear in another. It travels continuously as energy, but not as heat.

So it is with sound also. The sound-vibrations must be transmuted, must be delivered up to the æther to travel as radiation, and at the distant station it must be received by something which can transmute the energy back to sound again.

The transmutation of heat from matter into ætherial energy was effected by the atoms themselves by mechanism only partially known to us. Through all the geological ages—literally from time immemorial—it has been going on. Not so with sound. No trace of sound reaches us from an exploding star. We see the flash; we hear nothing. To transmute sound into an ætherial tremor and to change it back again into sound at a distant station requires human agency. It needed discovery and invention. Discovery and invention are rife among us though handicapped in their early stages by poverty and lack of opportunity. Only when some practical result is forthcoming does that difficulty begin to disappear. Faith in the power of discovery, latent in not a few of our strenuous youth, would accelerate the process. Faith removes obstacles and gives to genius its chance. Other nations will soon be beginning to realise this if we do not.

Great achievements are not due to one man, but to a succession of workers, each passing on the torch to the next. Each man's life is too short for extensive achievement. The great building rises, stone by stone, but it takes generations to complete—nay, it is never completed.

The long chain of discoverers has no end and no specifiable beginning. One can but pick out a few salient peaks. Nor is it one line only; it is a branching line. Different paths seem to converge on some one goal. It is well to remember great names of recent times—Kelvin, Maxwell, FitzGerald, Hertz, the pioneers on one line, and on another Crookes, J. J. Thomson, and others who are working hard to-day. The first line dealt with the æther and its properties; the second line discovered the nature of electricity.

It is only with scientific principles that I am dealing, not with the technical details of application. Methods of application are protean; many an amateur is acquainted with them, and the subject is advancing so quickly that devices a few years old may hiss the speaker; each twelvemonth teems a new one; but the fundamental principles remain, and one of these is the nature of electricity. It has turned out to be corporeal, atomic, or, rather, electronic. The discovery which closed the nineteenth century was the isolation of the natural unit of electricity. Small almost beyond conception, mobile and active to an extraordinary degree, the electron is becoming our most docile servant. The skill of man has harnessed electrons, and it is by their aid that sound-vibrations can be transmitted to the æther, and, after transit across great vasts of space, can be transmuted back again. In an empty Crookes's tube they can be driven off from matter. From a hot wire they evaporate, and they can be deflected and guided as we wish. Their obedience is absolute and instantaneous; they have next to no inertia or sluggishness of their own, and they obey the slightest force. An electric pole attracts or else repels them, according to its sign, and so their motions can be encouraged or can be checked.

If faced with a positive plate they rush to it; if the plate is negative they retire discouraged. Their journey is itself an electric current, and thus we get an electric current varying and responding to every fluctuating control. Electric oscillations are known. We owe them to Kelvin and FitzGerald. They are of extraordinary frequency—millions of vibrations per second—and they generate waves in the æther, as was shown by Maxwell and Hertz.

Let us, then, arrange a microphone, an ordinary telephone transmitter to which we can talk in the ordinary way, and let the slow sound-vibrations—a few hundred per second—be applied to strengthen or weaken electric oscillations of a few million per second. Thousands of oscillations occur during the time that every sound-wave lasts, and by letting them control a crowd of electrons in an exhausted vessel or vacuum tube their intensity can be controlled by every ripple, every rustle, every shock, and every sibilant which go to constitute human speech; and the radiation emanating from the electric oscillations will then be graduated in intensity so that the waves which travel in the æther shall be strong or weak exactly as the stimulus requires.

Receive the electric waves and convey them to another empty bulb containing again a hot wire giving off electrons; the crowd of particles respond, another current is generated, carved into fluctuations of corresponding strength, and these variations of current, when employed to actuate a telephone, can accurately reproduce the tones of the distant voice.

Roughly and generally that is the plan, and the astonishing feat is carried out by various ingenious devices. I was not specially astonished by the wireless transmission of coarse signals like the dot and dash of ordinary telegraphy. It is no more difficult to send impulses across space than to guide them by wires. What Mr. Marconi has made practical as "wireless" might have come in first, and then wires might have been regarded as an improvement, like speaking through a tube instead of shouting into the open air. Any mechanical sending key and many a mechanical relay can accomplish that, but no mechanical relay could follow the variations of quality in human voice; no agency short of the electron would be quick and docile enough; but with their aid the feat is accomplished, and the electric waves which act as the intermediary can travel a thousand miles or more before being received and once again transmuted.

One more principle I must emphasise. How can the human ear or any instrument follow vibrations of millions a second? It cannot. Only the electron can do that. But suppose that, in addition to the oscillations coming from a distant station, we set up home oscillations in a small subsidiary vacuum tube of nearly the same frequency. Let the incoming waves vibrate a million times, for instance, while our local arrangement vibrates a million *plus* 500. What will happen? They will "beat." They will give 500 beats a second, and that is a musical note. To that we can listen, and upon that the variations of intensity can be superposed.

This is not the first plan adopted. The first plan was the utilisation of crystals and other detectors, such as the Fleming valve, to rectify the oscillation, to check all the negative pulses and utilise all the positive, to let only one sign through. Thus we got the vacuum valve. But soon this was improved by Lee Forest into a magnifier, so that an original impulse, exceedingly weak, could be strengthened a hundred or even a thousand times by using the electrons as relays and putting a number of relays in series.

So also for transmitting, the magnifying device is available. The electric impulses from the first valve, the one directly actuated by the microphone —these need not be given to the æther; they can be used to stimulate another valve, so as to increase their intensity until the waves generated are powerful enough to be allowed to rush across the Atlantic. This they are able to do in a fraction of a second. And there, though what arrives is only a feeble residue, since they have spread far and wide by that time, yet they preserve all their peculiarities intact, every pulse of the speech is retained and can be reproduced, and by adequate magnification can be made easily audible.

Distance is no deterrent; it only enfeebles; it does not confuse and spoil, as it does with a wire embedded in the ocean. The properties of the æther are perfect, and all the fluctuations are accurately conveyed. All that we require is a magnifier to get a convenient intensity, and that the ingenuity of man has supplied. We have learnt to communicate efficiently across space void of matter. Possibilities are thus opened up the end of which no man can foresee.

Variations of Climate since the Ice Age.[1]

By C. E. P. BROOKS.

THE nineteenth century envisaged the Ice age as a remote catastrophe, sharply separated from the changeless present. The past twenty years have reversed that view; geologists and botanists have traced considerable fluctuations of temperature and rainfall extending from the last (Würmian) glacial period into historical times, while archæologists, working backwards from the present, have met them at the dawn of history with conditions appreciably different from those of to-day. In the countries bordering on the North Atlantic at least, the facts have been laid down with security, and it is now the task of meteorologists to elucidate the various distributions of pressure and winds which were associated with these changes of climate.

At the present day the great ice-sheets of Greenland and the Antarctic Continent are occupied by permanent areas of high pressure, and we may infer that the Quaternary ice-sheets of northern Europe and North America were occupied by similar anticyclones, with dry easterly winds on their southern borders. In Europe at least there is direct evidence of this in a belt of "fossil dunes" extending from Russia to Holland; these dunes are crescent-shaped with their convexities to the east, indicating that they were formed by easterly winds. The Atlantic must have been a

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[1] Abridged from a paper in the Quarterly Journal of the Royal Meteorological Society, July, 1921, pp. 173-94.